NOCTURNAL TEMPERATURE INVERSIONS NEAR THE GULF COAST

551.524 (764) (763)

By RAY A. DYKE

[Weather Bureau office, New Orleans, La.]

Temperature inversions have been studied carefully in some regions of rugged topography and well-defined air drainage, with considerable temperature differences between stations variously located. But in the more level regions there seems to be less opportunity for practical application of temperature studies of the lower air in the vertical dimension. Yet the study has promise of application that at first may not be obvious.

On the Plains near the coasts of Texas and Louisiana the conditions most favorable for nocturnal temperature inversions in winter occur in that part of areas of high pressure in which pressure gradients are slight, embracing areas of considerable extent, in which the winds may be northerly or westerly but sometimes easterly or southerly after the crest of the area of high pressure has passed. Steeper pressure gradients may prevail on the morning before the first night of an inversion, but the changes to slight gradient may usually be foreseen. In most instances the free-air velocities a few hundred feet above the ground and generally within the inversion layer are not far from the average velocities for the elevation, the interference induced by turbulence largely ceasing at sunset at such elevations, while at the ground increasing density and friction retard and almost halt air movement.

In an investigation of minimum temperature differences, in order to relate minimum temperature forecasts for the principal stations to the minimum temperatures recorded at substations, comparison has been made for some stations near the Gulf coast, showing the differences between roof and ground exposures. Among the influences that may tend to increase the amount of difference that occurs with nocturnal inversion we may mention city heat, dust, smoke, and surface differences, with concrete, stone, and brick contrasting with lawns, trees, and frame dwellings. Furthermore, the stations are some miles apart instead of one above the other. Yet we know that under favorable atmospheric conditions inversion will occur whether the city be present or not.

It should not be assumed, a priori, that all the city influences operate to increase the minimum temperatures of a station on a city roof. Roofs are good radiators, as is visibly illustrated when slate roofs are coated with frost at a height of 30 to 40 feet above the ground. There should be good insulation between a flat roof and the rooms below it, though radiation from the roof surface implies some conduction. The structures in a city increase the total radiation surface but communicate heat also. The net result of all the factors appears to be a slight increase in temperature due to city influences, but we are told that the growth of a city and a multiplication of its heat-producing power does not change its climate, a conclusion that is well supported by the evidence of comparative records (*1*) (*2*).

In order that the currents from ventilators may noticeably affect the minimum temperature readings, it is necessary not only that the wind come from certain narrowly limited directions when the temperature is lowest but also must be strong enough to turn the current against the thermometer shelter. Observations of the angle of ascending smoke at New Orleans indicate that air currents from ventilators on the post-office building are not likely to affect the temperature readings under conditions favorable for temperature inversion.

The smoke produced by orchard heaters designed for smokiness is no doubt denser than that overlying our cities near the Gulf coast, though not so extensive. Young (*3*), using a Weather Bureau pyrgeometer, found that the radiation measured under smoke produced by smoky orchard heaters during nights at Pomona, Calif., and Medford, Oreg., was reduced by about 10 per cent as compared to air where the smoke was not present. The effect on surface temperatures can only be conjectured; but if a 20° to 30° fall in temperature at night is diminished by only 2° to 3° when the smoke is very dense the lighter smoke of most cities may be expected to have less effect. Differences of 14° to 18° sometimes occur between the roof station and the nearest suburban or cooperative station, and we may safely infer that much the larger part of the difference is due to nocturnal radiation, with resulting inversion.

Differences in minimum temperatures, under given sky conditions and wind movement, have been computed for stations in New Orleans. New Orleans No. 1 is the principal station, with thermometers 11 feet above the roof of the post-office building and 76 feet above the ground. The anemometer is 84 feet above the ground.

The station known as Carrollton is within New Orleans, on the grounds of Loyola University, and faces the avenue bounding the narrow end of Audubon Park. Prior to 1926 the thermometer shelter at this station was located with the thermometers about 9 feet above sod on a rear lawn; but for the last few years the shelter has been about 50 feet above ground on a tower of one of the smaller buildings, which stands well isolated from surrounding structures, in a locality where the grass cover is extensive but not far from the paved avenue. The thermometer shelter is slightly larger and the slats thicker than Weather Bureau shelters, but admits air readily through its louvered sides.

Audubon Park station, known as New Orleans No. 2, is in the park, about 300 yards from the Mississippi River and about 1 mile from the Carrollton station, which is about 3½ miles from the New Orleans No. 1. The park is about one-half mile wide at the river end. Well built up residential sections lie on either side, with some industrial plants near to the west.

Light smoke, drifting slowly over the city, including the park, gives the latter a characteristic of city exposure, while the considerable expanse of vegetative cover gives it the character of a rural exposure. When the Audubon Park records are compared with those of other substations in southeastern Louisiana we find that with conditions favorable for radiation towns west of New Orleans along the river are in close agreement with Audubon Park, while minimum temperatures near Houma, in a rural location about 60 miles southwest of New Orleans, on clear nights of light wind movement as well as when windy conditions obtain, are usually 1° to 2° and sometimes 3° lower than the minimum temperatures at Audubon Park and have been still lower in a few instances during the onset of a cold wave. Not being near the large bodies of water that nearly surround New Orleans, Houma may be expected to have lower temperatures. The cold windy conditions also give lower temperatures along the river west of New Orleans than are recorded at Audubon Park.

The small differences between the minimum temperatures at Audubon Park and surrounding stations, when conditions are favorable for radiation, show that city smoke and dust have very little effect on temperatures 5 feet above the ground in a park in this city.

In Table 1 the New Orleans stations are arranged in the order of elevation. The record covers four years, except that a longer period was found necessary for the lower temperature, 32° or lower at New Orleans No. 1.

TABLE 1.—*Average minimum temperatures at stations in New Orleans, La.*

Sky and wind conditions	Number of instances	Average temperatures: Audubon Park, 5 feet	Average temperatures: Carrollton, 9 feet	Average temperatures: Carrollton, 50 feet	Average temperatures: New Orleans No. 1, 76 feet	Differences
		°	°	°	°	°
Clear, with wind movement 7 miles per hour or less	87	43.1	46.2	47.3	51.7	8.6
	81				51.9	5.7
	48				49.9	2.6
Clear, with wind movement more than 7 miles per hour	48	43.2	36.4	--------	45.7	2.5
	48				37.8	1.4
		Average temperatures 32° or less				
Clear, with wind movement 7 miles per hour or less	10	23.8	--------	--------	28.7	4.9
Clear, with wind above 7 miles per hour	21	24.8	--------	--------	26.3	1.5
Cloudy, with moderate to strong winds	19	28.8	--------	--------	29.1	0.3

NOTE.—There were no instances of light winds with cloudy weather (low clouds) during the nights when minimum temperatures were 32° or lower in the period used.

It is worthy of note that for wind velocities of 7 miles an hour or less the average difference between the lowest and highest stations is 8.6° on clear nights, but for winds of more than 7 miles an hour the average is only 2.5° F. For temperatures of 32° or lower, with winds 7 miles or less the average difference is 4.9° F.

For temperatures above 32° the greatest difference was 16°, March 21, 1922, when the minimum was 57° at New Orleans No. 1 and 41° at Audubon Park. An instance of considerable difference with frost occurred on December 2, 1916, when the minimum temperature was 47° at New Orleans No. 1 and 34° at Audubon Park. For temperatures below 32° the greatest difference since 1910 occurred on January 7, 1924, with 27° at New Orleans No. 1 and 18° at Audubon Park, with average hourly wind movement of 4 miles, which is an unusually low wind movement for the temperatures. The preceding night had been very cold, and though the night of the 6th and 7th was clear there was a fall of only 6° from the maximum of the 6th at New Orleans No. 1. This matter of slight fall from maximum to minimum at the roof station is worthy of further study. Quite recently, on December 3, 1929, we forecast a minimum temperature of 26° to 32° at New Orleans. Conditions were highly favorable for radiation. The temperature at New Orleans No. 1 fell from a maximum of 41° to a minimum of 39°, while at Audubon Park the fall was from 43° to 28°. Great damage occurred with this freeze in the sugar region, where minimum temperatures of 22° to 28° occurred as forecast, with a temperature of 24° continuing for three hours in much of the sugar region.

That the inversions are less for the lower temperatures, when winds are alike, is in accordance with theory. The lower the temperature of a body the less heat it has to radiate, the rate of radiation varying directly with the fourth power of the absolute temperature of the body, according to the physicists. In addition, as the surface of the soil grows colder conduction from beneath is increased to balance the loss of heat at the surface. In other words, lowering the temperature increases the effect of the reserve supply of heat on the temperature, and this applies not only to the reserve in the soil but also to other sources of heat such as are found in a city.

Since the temperature fall at the ground is less with the lower temperature the air at a higher elevation is cooled less and the difference between the maximum and minimum at the roof station is relatively smaller than when there is greater cooling at the ground.

Referring again to Table 1, we note that the effect of increasing elevation may be seen in the reduced difference between New Orleans No. 1 and Carrollton after the thermometers were placed higher at Carrollton.

Recent records for Houston and Harrisburg, Tex., compared for temperatures of 32° or lower at Harrisburg and the minimum temperatures, with other conditions, at Houston, are averaged in Table 2. These records, while not strictly on the same basis as the comparison made at New Orleans, are available at the present writing and will serve to illustrate inversion.

Houston is on the southeastern plains of Texas, with ground elevation about 50 feet above mean Gulf level. Since November, 1926, the anemometer has been exposed 314 feet above ground on the roof of one of the tallest buildings, and the period of this study begins with this date. The thermometers are 292 feet above the ground and 10 feet above the roof.

Harrisburg, about 7 miles southeast of Houston, with ground elevation 38 feet and thermometers 5 feet above the ground on a level prairie, represents rural conditions.

TABLE 2.—*Average minimum temperatures on clear nights at Houston and Harrisburg, Tex.*

[For nights with minimum temperatures 32° or lower at Harrisburg]

	Number of instances	Harrisburg	Houston	Difference	Greatest difference	Date	Least difference	Date
		°	°	°	°		°	
Wind less than 9 miles per hour	6	27.8	43.0	15.2	17	Jan. 28, 1928	14	Dec. 21, 1928 Dec. 23, 1928
Wind 9 to 13 miles per hour	17	27.8	37.3	9.5	16	Dec. 24, 1928	1	Jan. 4, 1928
Wind 14 miles per hour or more	21	28.5	29.2	.7	16	[1] Nov. 22, 1928	−4	[2] Dec. 31, 1927
	For minimum temperatures 32° or less at Houston							
Wind 9 to 13 miles per hour	4	23.8	27.8	4.0	6	Jan. 7, 1929	1	Jan. 4, 1928
Wind 14 miles per hour or more	10	25.9	25.8	−.1	4	Feb. 11, 1929	−4	[2] Dec. 31, 1927

[1] Winds up to midnight, Nov. 21–22, 1928, 8 miles per hour. Windy therafter but inversion not overcome. Strong inversion on this date at Groesbeck, Tex., with light wind at ground and fresh to strong at 250 meters above the ground.

[2] Temperature higher at Harrisburg than at Houston, with difference of 4°. Strictly, the least difference was 0.

It will be seen that the upper group in Table 2 is inclusive of temperatures in the lower group; but no temperatures of more than 32° F. at Houston are included in the lower group. As there are not many instances of temperatures of the lower group, the results are not essentially altered by making the upper group exclusive of the lower group.

The average wind movement for clear nights in which the temperature differences between Houston and Harrisburg averaged 15.2° F. was 7 miles per hour, and for the clear nights, with average difference of 9.5°, was 11.7 miles. For winds of 14 miles or more per hour the average temperature difference was negligible.

On nights with low clouds the minimum temperatures were about the same. A moderate difference sometimes occurred with high clouds and low or moderate wind movement. If conditions are favorable for inversion, cirrus clouds have slight effect in reducing the amount of inversion.

Sometimes for the part of a night the wind velocity increased to much above the averages stated, but if there was considerable inversion there were nearly always at least a few hours in which the wind movement at the roof exposure was light. In some instances the lighter winds would occur in the first half of the night and in other instances in the second half, or they might be separated by a few hours of stronger winds. The stations are 7 miles apart, which may account for one exception, hereafter referred to.

As Young (*4*) showed by observations on a wireless tower in a valley near Medford, Oreg., it does not require an entire night to produce a large inversion of temperature. Inversions in that locality were fully reached at 11 p. m., without increase thereafter, while the temperature fell at both the stations, upper and lower.

The records of instruments carried by kites show not only the nocturnal inversions due to the cooling earth but also other inversions at higher levels which occur rather frequently because of clouds and moving air layers from different sources.

The aerological station near Groesbeck, Tex., is surrounded by a nearly level plain, with slight depressions due to small water branches. The principal nocturnal inversions over the Groesbeck station in the period November 1, 1927, to January 31, 1929, have been compiled. Most of the flights were started at or shortly before 6 a. m., ninetieth meridian time, and some at 7 to 8 a. m. For wind records we have the hourly readings of the station anemometer 55 feet above the ground. The early morning balloon flights provide an approximation of the wind velocity 820 feet above the surface. The kites are reeled off rapidly when launched, but a stop is made at 500 meters out in order that the instrument may adjust itself. Records could not be secured in several instances favoring inversion because of winds too light to secure a flight. The averages computed for this rather short record are as follows:

Average top of inversion above ground, 303 meters, or 993 feet, with individual instances ranging from 456 feet (inversion 17° F., January 27, 1928) to 1,834 feet (inversion 13.5° F., November 18, 1927). The surface temperatures in these instances were mostly near the freezing point.

Average amount of inversion, 7.1° C., or 12.8° F., with individual instances ranging from 21° F., with top of inversion 1,178 feet (November 22, 1928) to 5° F., with top also 1,178 feet (December 9, 1927).

Average wind movement, 7 p. m. to 7 a. m., 55 feet above the ground, 6 miles per hour. No large departures from the average occurred in the single hours.

Average wind movement in early morning at 250 meters, or 820 feet, above the surface, 10 meters per second, or 22 miles an hour.

The increase of wind velocity with height is characteristic. At 55 feet above the ground only one night out of 17 instances had an hour or more recorded as calm. This occurred during the night of December 2–3, 1927, with inversion of 21° F. in 719 feet, when the minimum temperature was 28° at Harrisburg and 42° at Houston. This is the exceptional instance at Houston, previously referred to, when wind at 314 feet above the ground moved 12 to 20 miles an hour through the night during a considerable inversion.

During the period studied when marked inversions were noted at Houston inversions were recorded also at Groesbeck if a kite flight was made.

As many of our principal stations have the thermometers on the roofs of buildings, much comment results when ice-covered puddles are seen in the streets, though the official record of the thermometer may be above the freezing point. When the matter is explained the question is asked: "If the daily temperature range decreases with height, why does not the Weather Bureau secure its official readings nearer the ground at all stations?" There are good reasons for roof exposure of the thermometers at most of our principal stations. Even where near-by open squares or lawns are available, and they are not in many instances, we can not place guards over the instrument shelters to prevent vandalism and theft which would all too frequently cause loss of records as well as of instruments exposed near the ground in cities.

It is believed that the method of grouping data used in this paper will be found profitable in the study of minimum temperatures elsewhere. The groups of temperature selected should be subgrouped according to wind movement during the night. The limits of this paper will not permit a consideration of dew point, relative humidity, and maximum temperature as observed in the evening of the preceding day, but related data should be included. Instances of snow cover, well-frozen ground, the kind and amount of clouds, and the character of frost, if any, should be included while obtaining the other data.

Averages of minimum temperatures under all conditions are insufficient for some purposes. Some grouping of similar conditions is necessary if we are to have the knowledge that will be most effective in advising the public what temperatures to expect in order that crops may be saved, plumbing and radiators protected, concrete work suspended when necessary, shipments handled without damage, and other activities delayed when advisable or successfully pursued.

REFERENCES

(*1*) MINDLING, GEORGE W.
Influence of Artificial Heating on the Climate of Cities. MONTHLY WEATHER REVIEW, August, 1911, vol. 39, pp. 1280–1283.

(*2*) PALMER, ANDREW H.
Is the Heat Generated by Great Cities Changing Their Climates? MONTHLY WEATHER REVIEW, August, 1911, vol. 39, pp. 1284–1286.

(*3*) KIMBALL, HERBERT H., and YOUNG, FLOYD D.
Smudging as a Protection from Frost. MONTHLY WEATHER REVIEW, August, 1920, vol. 48, pp. 461–462.

(*4*) YOUNG, FLOYD D.
Nocturnal Temperature Inversions in Oregon and California. MONTHLY WEATHER REVIEW, March, 1921, vol. 49, pp. 138–148.